DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

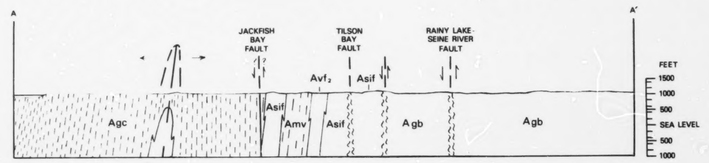
Base from U.S. Geological Survey International Falls, Ranier, Island View, and Cranberry Bay quadrangles, 1969, revised 1983

SCALE 1:24 000

1 0 1 MILE

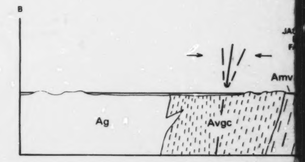
1 .5 0 1 KILOMETER

A A'



Section A A'

B



CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

EARLY PROTEROZOIC

Pid Gabbro, diorite, and diabase—Dark-green dikes, none of which are mapped. Dikes correlate with regional northeast-trending 2,120 Ma (Davy and Sims, 1984) dike swarm described by Beck and Murthy (1981).

Ahm Mafic intrusive rocks—Dark-gray to black, fine- to medium-grained gabbro, diorite, and quartz diorite. Forms small plugs and dikes. Yields a U-Pb zircon age of 2,680 Ma (Davy and Sims, 1984).

Ahd Diorite—Medium-gray, fine- to medium-grained hornblende diorite. Forms small plugs and dikes. Yields a U-Pb zircon age of 2,680 Ma (Davy and Sims, 1984).

Ag Granitic rocks—Pink to light-gray, fine- to medium-grained, equigranular to porphyritic granite and granodiorite. Forms small plugs and dikes. Yields a U-Pb zircon age of 2,680 Ma (Davy and Sims, 1984).

Ac Conglomerate—Strongly flattened conglomerate clasts composed of cobble- to boulder-sized mafic to felsic volcanic and pyroclastic rocks intermixed with chert, biotite schist, and felsic plutonic rock clasts. Clasts are derived from units Amv, Avf_{1-3}, and Agit. The matrix is composed of biotite and chlorite schist. Interpreted as an intraformational conglomerate within unit Amv

Agit Tonalite of Grassy Island—Light-gray medium-grained foliated biotite tonalite. The unit has been affected by extensive sericitic alteration and cataclasis. Within the eastern part of this intrusion, the southern margin grades from biotite-hornblende diorite of unit Agid northward to tonalite into biotite trondhjemite along the northern margin. The unit forms a subvolcanic intrusion into the Metavolcanic rocks of unit Amv

Agid Biotite-hornblende diorite of Grassy Island—Dark-green medium- to coarse-grained rock forms border phase of unit Agit; intrusive into unit Amv

Avf_3 Dacite—Light-gray to buff, well-foliated dacite and dacitic tuff. Oxidation of sulfide minerals has produced light-brown ocher stain along fractures and planes of foliation. Extent of unit approximated due to limited exposure, present only in western part of area

Avf_2 Carbonate-rich dacite tuffite—Light-gray quartz-rich dacite tuff and possibly reworked volcaniclastic sediment interbedded with thin (0.5-20 cm thick) carbonate zones. Western part of unit is well laminated, and contains a greater proportion of pyroclastic and carbonate-rich rocks. Almandine garnet developed in more pelitic layers of pyroclastic sediment (Hill/Mehlig, loc. cit.)

Agb Sedimentary rocks, undivided—Predominantly medium- to dark-gray biotite graywacke with minor intercalated amphibolite. Occurs south of the Rainy Lake-Seine River fault. Ojakangas (1972) noted that graded beds throughout unit generally young to the north. Amphibolite facies assemblages are biotite, chlorite, garnet, sillimanite, plagioclase (An 25-30), quartz, white mica, minor magnetite, and potassium feldspar (trace). Correlation with unit Agc is uncertain

Agc Graywacke—Medium- to dark-gray chlorite and biotite graywacke. Graded bedding is locally preserved. Typical beds are 5 to 10 cm thick, but range up to 2 m. Unit occurs throughout northern part of the mapped area. Southern contact with unit Amv exposed on the northeast end of Jackfish Island is gradational. Southern contact is not exposed in the western part of the map area, but is inferred to be a fault. Greenschist facies metamorphism has produced assemblages of chlorite, biotite, sodic plagioclase, quartz, white mica, and magnetite

Amv Mixed volcanic flows and tuff, undivided—Thin basalt flows and rare pillowed basalt interfinger with subordinate amounts of felsic volcanic rock, and schistose tuff of variable composition. Felsic volcanic rocks are dark gray and contain characteristic doubly terminated blue quartz phenocrysts. Locally intercalated throughout the southern portion of the unit are thin beds (0.5-20 cm thick) of chemical sediments consisting of lean iron-formation, pyrite- and pyrrhotite-bearing cherty zones, and discontinuous calcite and siderite zones. Greenschist facies metamorphism has developed actinolite, biotite, and chlorite alteration and has totally recrystallized the tuffaceous parts to chlorite and biotite schist

MAP SYMBOLS

- CONTACT--Approximately located
- HIGH-ANGLE FAULT--Approximately located, dashed where trace is submerged
- SHEAR ZONE--Approximately located, dashed where trace is submerged. See description for unit At
- OVERTURNED ANTICLINE--Showing approximate trace of axial surface and direction of plunge
- OVERTURNED SYNCLINE--Showing approximate trace of axial surface and direction of plunge
- BEARING AND PLUNGE OF MINOR FOLDS
- BEARING AND PLUNGE OF MINOR ANTICLINE
- BEARING AND PLUNGE OF MINOR SYNCLINE

STRIKE AND DIP OF BEDS

- Inclined, top direction undetermined
- Inclined, right side up
- Inclined, overturned

NOTES ON STRATIGRAPHY, AGE, AND STRUCTURE

The Rainy Lake area is a fault-bounded structural terrane situated along the boundary between the Wabigoon (on the north) and Quetico (on the south) subprovinces of the Superior province. The area lies within a dextral wrench zone bounded on the north by the Quetico fault and on the south by the Rainy Lake-Seine River fault (see index map) (Poulsen, 1983). The Wabigoon subprovince is comprised of ultramafic to felsic volcanic rocks and their compositionally equivalent plutonic rocks, along with volcanigenic, chemical, and epiclastic sediments. The Quetico subprovince, on the other hand, is comprised primarily of volcanigenic graywacke and granite (Goodwin, 1978). Within the study area, the rocks of the Wabigoon subprovince have experienced low grade (upper greenschist-facies) metamorphism, whereas those of the Quetico subprovince have experienced middle grade (lower to middle amphibolite-facies) metamorphism.

The quality and quantity of outcrop is good to excellent along the shorelines in the northeastern part of the map area. However, outcrop abundance decreases rapidly away from the shoreline to the south and southwest, and consequently the lithologic contacts are inferred in areas with minimal outcrop.

The nomenclature used for the igneous rocks follows the classification outlined by Streckeisen (1973). For the sake of brevity and clarity the prefix "meta-", which is commonly used to modify metamorphosed-rock names, is not used here because all rocks have undergone at least upper greenschist-facies regional metamorphism.

Age

Geochronological studies on the Archean units in the Rainy Lake area by Tilton and Grunenfelder (1968), Hart and Davis (1969), Peterman and others (1972), and Goldich and Peterman (1980) have shown that all the major rock-forming events occurred between 2,750 and 2,600 Ma. U-Pb isotopic work by Hart and Davis (1969) and Goldich and Peterman (1980) on zircon and sphene from units correlative with map units Amv, Agit, and Agc indicate that they lie on a 2,750±30 Ma Concordia chord. The apparent Rb-Sr whole-rock age for these units is slightly younger, ranging from 2,700 to 2,500 Ma. They have suggested that the younger Rb-Sr whole-rock ages represent partial isotopic re-equilibration that occurred during regional metamorphism and tectonism. Recent work by Goldich (1984), using an abrasion technique on zircon and titanite, has yielded an U-Pb age of 2,735 Ma for synkinematic tonalite and granodiorite similar to unit Agit, and an age of 2,680 Ma for post-tectonic granodiorite and granite similar to unit Ag.

Structural observations

At least three phases of deformation are recorded in the map area. The first (D_1) was an episode of large-scale folding that produced the southwest-plunging an echelon F_1 folds in unit Agc. The F_1 folds are tight and non-cylindrical, and are overturned to the southwest; the axial planes strike N65°±5°W and dip 82°±5°NE. Using the criterion reviewed by Wilson (1982), both the large-scale and parasitic F_1 folds are upward-facing. An early regional S_1 schistosity (fig. 1) is developed axial planar to both the large-scale and parasitic F_1 folds (fig. 3). In addition to folding, D_1 was an episode of strong apparent flattening. In unit Agc, S_1 is moderately developed subparallel to the original S_0 bedding. However, in all units south of the Jackfish Bay fault the D_1 deformation was more intense. Pillow structures in lava flows have been flattened parallel to the regional S_1 schistosity, and have dimensions of as much as 2 m long and 0.1 m thick. Pebble- to boulder-sized clasts in the conglomerate units have also been strongly flattened parallel to the regional S_1 schistosity. Stretching lineations are rare, but where present they plunge to the southwest.

Tectonic interpretation

Oblique convergence along a tectonic axis of maximum compression oriented northwest-southeast caused the regional dextral shear couple that was active along the bounding fault zones represented by the Rainy Lake-Seine River and the Quetico faults. The rocks within the map area have undergone incremental ductile deformation in response to the regional transcurrent tectonic regime.

The earliest phase of deformation (D_1) produced the upward-facing en echelon F_1 folds, and presumably caused early folding in the rocks along structural trend in Ontario. Poulsen and others (1980) reported that the stratigraphic succession was overturned possibly as a result from early recumbent folding in the Rice Bay Dome area in Ontario, which is approximately 20 km to the northeast along strike with the map area. In addition, the overturned graywacke units in the Rice Bay Dome area have been metamorphosed to sillimanite-bearing amphibolite-facies, whereas the rocks in this map area (unit Agc) have undergone only biotite-bearing greenschist-facies metamorphism. Based on the assumption that the earliest folding in both Ontario and Minnesota was coeval, Day and Sims (1984) proposed that the rocks in Minnesota are on the upper (upward-facing) limb and the rocks in Ontario lie on the lower (downward-facing) limb of a major southeast-plunging recumbent fold. In this model the region was differentially exhumed during erosion, exposing the higher-grade metamorphic rocks in Ontario that reflect the higher temperature and pressure conditions experienced by the lower, more deeply buried limb of the recumbent fold(e).

Direct correlation between D_1 structures in the two areas is equivocal because of the unknown amount of displacement along the intervening high-angle faults. If displacement along the faults was minimal, then the model proposed by Day and Sims (1984) is possible. However, Ojakangas (1972) suggested that movement along the faults was significant.

Nevertheless, the early F_1 folds developed prior to or during the earliest phases of the regional wrench zone tectonism. As deformation proceeded, the apparent flattening of the early D_1 structures intensified. D_1 elements in the region south of the Jackfish Bay fault rotated parallel to the boundary shear zones (represented by the Jackfish Bay and Rainy Lake-Seine River faults). The younger S_1 cleavage and minor F_1 folds were progressively superimposed on the early D_1 tectonic fabric. On the outcrop scale, successively younger foliations fan in orientation from the original S_1 schistosity into the later S_2 cleavage. Clasts and early boudins were deformed into sigmoidal shapes, with strong flattening in S_1 and tails reoriented into the S_2 cleavage direction.

Notion along the high-angle faults probably started during mid- to late-D_2 deformation. Initially, deformation within the fault zones was ductile, producing the phyllonite and protomylonite. During the waning stages of D_2 deformation within the fault zones became more brittle, as recorded by the development of pseudotachylite within the Rainy Lake-Seine River fault zone. Motion along the high-angle faults was terminated by the time of emplacement of the northwest-trending 2,120 Ma diabase dike swarm.

REFERENCES CITED

Beck, W., and Murthy, V. R., 1982, Rb-Sr and Sm-Nd isotopic studies of Proterozoic mafic dikes in northeastern Minnesota [abs.]: 28th Institute on Lake Superior Geology, Mineralogical Palle, Minn., Proceedings, p. 5.

Day, W. C., and Sims, P. K., 1984, Tectonic evolution of the Rainy Lake area, northern Minnesota [abs.]: Joint annual meeting, Geological Society of Canada and Mineralogic Society of Canada, v. 9, p. 27.

OPEN-FILE REPORT 85-0245
SHEET 1 OF 1

GEOLOGY OF THE RAINY LAKE AREA, ONTARIO AND MINNESOTA

by
Peter C. Thurston, Ontario Geological Survey
Gordon R. Ojakangas, Minnesota Geological Survey

Mapped July-September, 1983, and with Bruce Brassard, August, 1984. Additions from reconnaissance mapping by Ojakangas (1972) and Southwick and Ojakangas (1979).

SCALE 1:24 000

1 0 1 MILE

1 0 1 KILOMETER

Section A A'

Section B B'

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Direct correlation between D_1 structures in the two areas is equivocal because of the unknown amount of displacement along the intervening high-angle faults. If displacement along the faults was minimal, then the model proposed by Day and Sims (1984) is possible. However, Ojakangas (19/2) suggested that movement along the faults was significant.

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REFERENCES CITED

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Day, W. C., and Sims, P. K., 1984, Tectonic evolution of the Rainy Lake area, [illegible] Geological Society of

MAP SYMBOLS

[illegible]tely located

[illegible]Approximately located, dashed where trace is

[illegible]imately located, dashed where trace is submerged.

[illegible]on for unit At

[illegible]showing approximate trace of axial surface and

[illegible]showing approximate trace of axial surface and

[illegible] POLES

[illegible] ANTICLINE

[illegible]

[illegible]

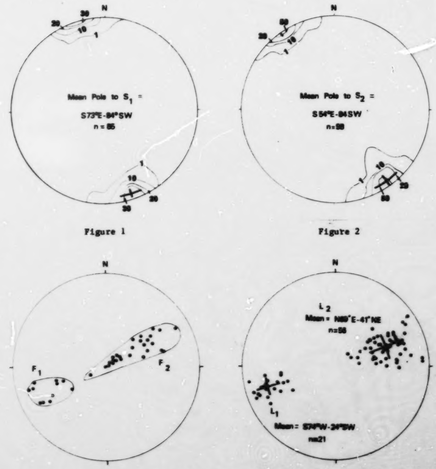


Figure 1

Figure 2

Figure 3

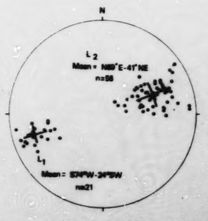
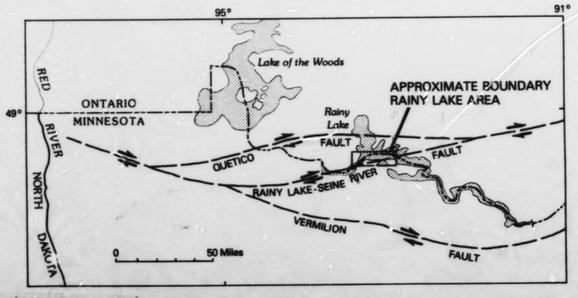
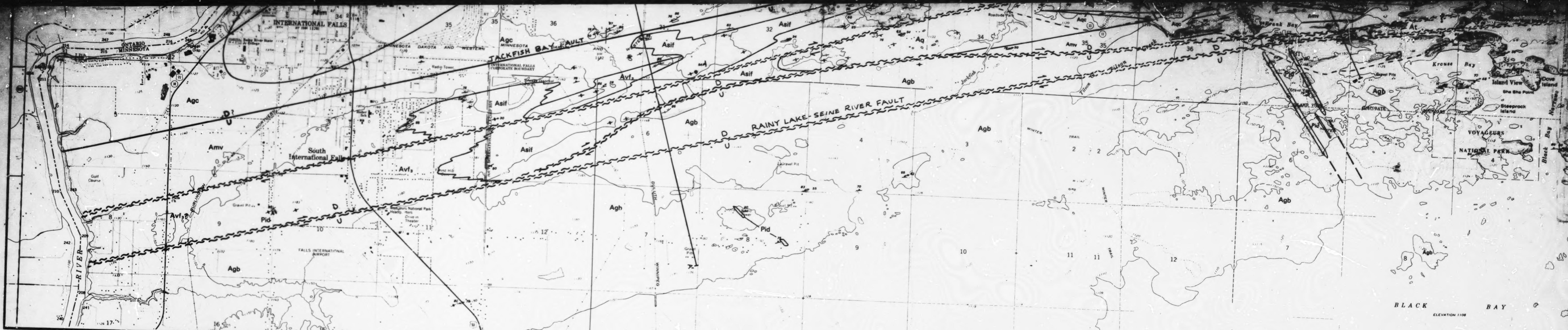


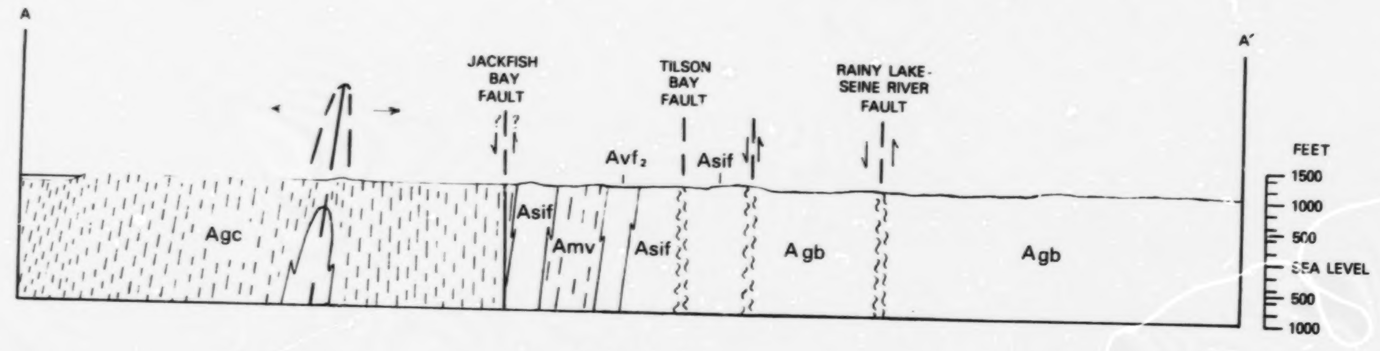
Figure 4



Index map showing the location of the Rainy Lake area



Base from U.S. Geological Survey International Falls, Ranier, Island View, and Cranberry Bay quadrangles, 1969, revised, 1983

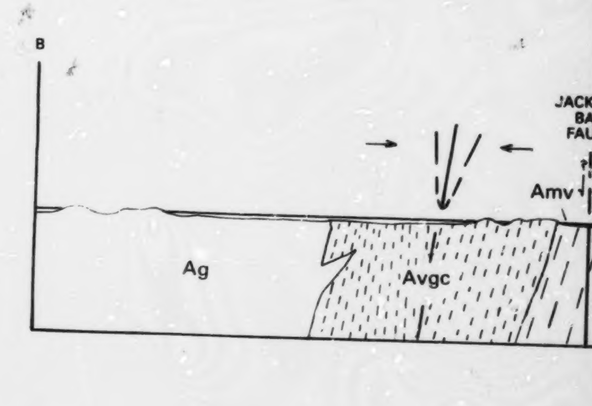


Section A A'

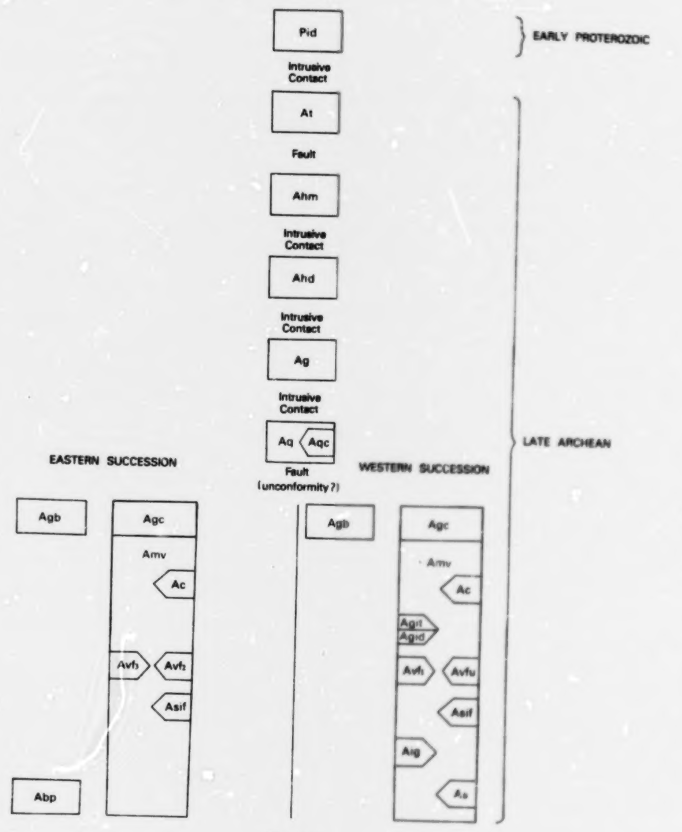
SCALE 1:24 000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER



CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

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LATE ARCHEAN

At — Mylonite, breccia, and related rocks--Strongly foliated tectonite localized along faults and shear zones. Characterized by tectonic intercalation of various local lithotypes recrystallized to biotite and chlorite schist. The Rainy Lake-Seine River fault zone is as much as 0.5 km wide and contains chlorite schist, protomylonite, and psuedotachylite. Small-scale drag folds are ubiquitous. Locally developed stringers and boudins are composed of quartz ± white mica ± calcite ± ankerite, with minor to trace amounts of pyrite ± pyrrhotite ± arsenopyrite

Ahm — Hornblende monzonite--Pink coarse-grained weakly foliated rock. Mapped extent estimated from limited exposure

Ahd — Hornblende diorite--Dark-green coarse-grained biotite-hornblende diorite. On north side of Eightmile Island the trend of the hornblende diorite body cross cuts foliation in biotite granodiorite. On island northeast of Tango Bay and north of Dryweed Island, hornblende diorite sill is interlayered with units Aq and Aqc

Ag — Granodiorite and granite--Light-gray to white hornblende biotite granodiorite is exposed east of Roberts Island. Enos Island and small adjacent islands are composed of light-gray to white hornblende biotite granite. Rock is well foliated, coarse-grained, and hypidiomorphic in texture. Foliation parallels regional structural fabric and is defined by mafic minerals and elongate diorite and basalt xenoliths

Aq — Feldspathic quartz arenite and minor conglomerate--Light-brown quartz arenite. Clasts range from typical coarse-grained angular to subangular quartz and subordinate feldspar. Local facies contain pebble- to cobble-sized polymict conglomerate. Conglomerate clasts are typically highly flattened parallel to the regional foliation. Matrix is predominately fine-grained quartz and white mica, but grades locally into facies rich in biotite and chlorite. Trough cross beds consistently young to south throughout unit

Aqc — Conglomerate--Polymict conglomerate with pebble- to boulder-sized clasts of felsic plutonic rocks, mafic to felsic volcanic rocks, chert, and iron-formation; clasts are supported by matrix of medium-grained biotite-rich sand. Basal contact is obscured by surficial cover and faulting. Unit Aqc is interbedded with Aq

Agb — Sedimentary rocks, undivided--Predominantly medium- to dark-gray biotite graywacke with minor intercalated amphibolite. Occurs south of the Rainy Lake-Seine River fault. Ojakangas (1972) noted that graded beds throughout unit generally young to the north. Amphibolite facies assemblages are biotite, chlorite, garnet, sillimanite, plagioclase (An 25-30), quartz, white mica, minor magnetite, and potassium feldspar (trace). Correlation with unit Agc is uncertain

Agc — Graywacke--Medium- to dark-gray chlorite and biotite graywacke. Graded bedding is locally preserved. Typical beds are 5 to 10 cm thick, but range up to 2 m. Unit occurs throughout northern part of the mapped area. Southern contact with unit Amv exposed on the northeast end of Jackfish Island is gradational. Southern contact is not exposed in the western part of the map area, but is inferred to be a fault. Greenschist facies metamorphism has produced assemblages of chlorite, biotite, sodic plagioclase, quartz, white mica, and magnetite

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Avf_3 — Dacite--Light-gray to buff, well-foliated dacite and dacitic tuff. Oxidation of sulfide minerals has produced light-brown ocher stain along fractures and planes of foliation. Extent of unit approximated due to limited exposure, present only in western part of area

Avf_2 — Carbonate-rich dacite tuffite--Light-gray quartz-rich dacite tuff and possibly reworked volcaniclastic sediment interbedded with thin (0.5-20 cm thick) carbonate zones. Western part of unit is well laminated, and contains a greater proportion of pyroclastic and carbonate-rich rocks. Almandine garnet developed in more pelitic horizons of pyroclastic sediment (SW1/4SE1/4 sec. 32, T. 71 N., R. 23 W.). Minor pyrite, pyrrhotite, chalcopyrite, and bornite are disseminated throughout unit. Present only in western part of area. Stratigraphically interfingers with unit Amv

Avf_1 — Dacite--Light-gray well-foliated biotite dacite with medium-grained plagioclase and characteristic doubly terminated blue quartz phenocrysts. Interbedded with unit Amv

Avfu — Felsic volcanic and volcaniclastic rocks - undivided. Relative age with units Avf_{1-3} uncertain. Used only in eastern part of area

Asif — Amphibolite schist and lean iron-formation--Medium- to dark-green chlorite-biotite amphibolite schist with characteristic radiating aggregates of calcic amphibole, intercalated with thin (0.5-20 cm thick), irregular calcite and siderite stringers, lean iron-formation, and dark-gray cherty zones. Minerals occurring throughout unit include calcic amphibole (ferrotschermakite), chlorite, biotite, muscovite, plagioclase, quartz, siderite, calcite, and magnetite. Almandine garnet, grunerite, and minor pyrite, pyrrotite, chalcopyrite, and bornite occur in the westernmost part

Aig — Gabbro--Dark-green ilmenite-bearing gabbro sill, northern and southern borders are medium-grained and grade inward to coarse-grained interior with irregular lenses of pegmatitic anorthositic gabbro. Relict mineralogy of pyroxene, plagioclase, and ilmenite partly to totally replaced by hornblende, sericite, biotite, and minor epidote, calcite, and quartz. Intrusive into Amv in eastern part of area

As — Serpentinite--Dark-green chromite-bearing ultramafic serpentinite, with minor talc and calcite. Exposure limited to small island northeast of Grindstone Island in eastern part of area. Contacts with unit Amv not exposed, but assumed to be intrusive

Abp — Basalt and mafic tuff--Foliated ilmenite-bearing basalt flows intercalated with pillowed basalt, schistose mafic tuff, and fine-grained mafic volcaniclastic sedimentary rocks. Pillow structures are flattened parallel to regional foliation. Greenschist facies metamorphism has produced assemblages of acicular actinolite, sodic plagioclase, biotite, and chlorite. Minor to trace amounts of pyrite, pyrrhotite, and chalcopyrite are disseminated throughout the metabasalt. Epidote, calcite, and quartz form late vein filling material. Correlation with unit Amv is uncertain. Unit occurs in a small area south of Birch Point in western part of map area

MAP SYMBOLS

CONTACT--Approximately located

HIGH-ANGLE FAULT--Approximately located, dashed where trace is submerged

SHEAR ZONE--Approximately located, dashed where trace is submerged. See description for unit At

OVERTURNED ANTICLINE--Showing approximate trace of axial surface and direction of plunge

OVERTURNED SYNCLINE--Showing approximate trace of axial surface and direction of plunge

60 BEARING AND PLUNGE OF MINOR FOLDS

26 BEARING AND PLUNGE OF MINOR ANTICLINE

74 BEARING AND PLUNGE OF MINOR SYNCLINE

STRIKE AND DIP OF BEDS

72 Inclined, top direction undetermined

72 Inclined, right side up

80 Inclined, overturned

Vertical, top in direction of dot

Vertical, top direction undetermined

S_1 SCHISTOSITY

70 Inclined, showing dip

Vertical

S_2 CLEAVAGE

80 Inclined, showing dip

Vertical

40 BEARING AND PLUNGE OF MINERAL LINEATION--May be combined with strike and dip of beds, schistosity, or cleavage

ABANDONED MINE OR PROSPECT

ABANDONED ADIT

APPROXIMATE LIMIT OF OUTCROP OBSERVED DURING MAPPING--Limited to area north of the Seine River-Rainy Lake fault; area to the south of the fault mapped on reconnaissance basis and limit of outcrop not delineated

AXIAL PLANE OF FOLD--Shown only on cross section, arrows indicate dominant top direction

NOTES ON STRATIGRAPHY, AGE, AND STRUCTURE

The Rainy Lake area is a fault-bounded structural terrane situated along the boundary between the Wabigoon (on the north) and Quetico (on the south) subprovinces of the Superior province. The area lies within a dextral wrench zone bounded on the north by the Quetico fault and on the south by the Rainy Lake-Seine River fault (see index map) (Poulson, 1983). The Wabigoon subprovince is comprised of ultramafic to felsic volcanic rocks and their compositionally equivalent plutonic rocks, along with volcanigenic, chemical, and epiclastic sediments. The Quetico subprovince, on the other hand, is comprised primarily of volcanigenic graywacke and granite (Goodwin, 1978). Within the study area, the rocks of the Wabigoon subprovince have experienced low grade (upper greenschist-facies) metamorphism, whereas those of the Quetico subprovince have experienced middle grade (lower to middle amphibolite-facies) metamorphism.

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Age

Geochronological studies on the Archean units in the Rainy Lake area by Tilton and Grunenfelder (1968), Hart and Davis (1969), Peterman and others (1972), and Goldich and Peterman (1980) have shown that all the major rock-forming events occurred between 2,750 and 2,600 Ma. U-Pb isotopic work by Hart and Davis (1969) and Goldich and Peterman (1980) on zircon and sphene from units correlative with map units Amv, Agit, and Agc indicate that they lie on a 2,750±30 Ma Concordia chord. The apparent Rb-Sr whole-rock age for these units is slightly younger, ranging from 2,700 to 2,500 Ma. They have suggested that the younger Rb-Sr whole-rock ages represent partial isotopic re-equilibration that occurred during regional metamorphism and tectonism. Recent work by Goldich (1984), using an abrasion technique on zircon and titanite, has yielded an U-Pb age of 2,735 Ma for synkinematic tonalite and granodiorite similar to unit Agit, and an age of 2,680 Ma for post-tectonic granodiorite and granite similar to unit Ag.

Structural observations

At least three phases of deformation are recorded in the map area. The first (D_1) was an episode of large-scale folding that produced the southwest-plunging en echelon F_1 folds in unit Agc. The F_1 folds are tight and non-cylindrical, and are overturned to the southwest; the axial planes strike N65°±5°W and dip 82°±5°NW. Using the criterion reviewed by Wilson (1982), both the large-scale and parasitic F_1 folds are upward-facing. An early regional S_1 schistosity (fig. 1) is developed axial planar to both the large-scale and parasitic F_1 folds (fig. 3). In addition to folding, D_1 was an episode of strong apparent flattening. In unit Agc, S_1 is moderately developed subparallel to the original S_0 bedding. However, in all units south of the Jackfish Bay fault the D_1 deformation was more intense. Pillow structures in lava flows have been flattened parallel to the regional S_1 schistosity, and have dimensions of as much as 2 m long and 0.1 m thick. Pebble- to boulder-sized clasts in the conglomerate units have also been been strongly flattened in S_1, with apparent length-to-width ratios of as much as 10:1.

The second phase of deformation (D_2) produced a moderate to strong regional S_2 cleavage (fig. 2) that clearly cross cuts all D_1 structures, including the large-scale en echelon F_1 folds mapped in unit Agc. The S_2 cleavage is axial planar to F_2 folds, which are generally small (0.1-to-1 m limb to limb) and have predominately Z-asymmetry (fig. 3). The plunge of F_2 fold axes ranges from shallow with northeast trends to nearly vertical. Overall, however, the fold plunge changes continuously from shallow southwest-plunging early F_1 folds, through steeply plunging folds oriented both southwest and northeast, to the shallow northeast-plunging younger F_2 folds (fig. 3), implying a gradational transition from D_1 to D_2.

Mineral lineations generated during both D_1 and D_2 are formed along the plane intersections of either S_0, S_1, or (and) S_2. The lineations cannot be definitively correlated with either D_1 or D_2 based solely on orientation. In general, L_1 lineations that demonstrably developed along the intersection of S_0 and S_1 plunge to the southwest, whereas L_2 lineations formed along the intersection of S_0 and S_1 plunge to the northeast (fig. 4). However, D_2 generation lineations also developed along the intersection of S_1 and S_2, yielding a wide variation in both trend and plunge.

The third episode of deformation (D_3) produced the high-angle faults and shear zones, the major one being the Rainy Lake-Seine River fault. Hawley (1929) noted that the horizontal component of motion on the Rainy Lake-Seine River fault was dextral. Metamorphic mineral assemblages on the north side of the Rainy Lake-Seine River fault are of upper greenschist facies, whereas those on the south side in rocks of equivalent composition are of amphibolite facies. These observations led Ojakangas (1972) to conclude that the south side of the Rainy Lake-Seine River fault has moved relatively upward, exposing rocks of higher metamorphic grade to the south.

Structural correlation

The Quetico sedimentary rocks (map unit Agb) south of the Rainy Lake-Seine River fault have also undergone multiple episodes of deformation. The first (D_1') produced a schistosity subparallel to bedding that developed during regional amphibolite-grade metamorphism. The second episode (D_2') produced a foliation that is counterclockwise to bedding similar to the S_2 developed in rocks north of the fault, as well as minor folds and mineral lineations. The orientation of all of the minor structures developed during D_2' (fig. 5), corresponds directly with the D_2 elements observed to the north implying that the D_2 structures north of the Rainy Lake-Seine River fault are coeval with the D_2' phase in the Quetico sediments.

Tectonic interpretation

Oblique convergence along a tectonic axis of maximum compression oriented northwest-southeast caused the regional dextral shear couple that was active along the bounding fault zones represented by the Rainy Lake-Seine River and the Quetico faults. The rocks within the map area have undergone incremental ductile deformation in response to the regional transcurrent tectonic regime.

The earliest phase of deformation (D_1) produced the upward-facing en echelon F_1 folds, and presumably caused early folding in the rocks along structural trend in Ontario. Poulsen and others (1980) reported that the stratigraphic succession was overturned possibly as a result from early recumbent folding in the Rice Bay Dome area in Ontario, which is approximately 20 km to the northeast along strike with the map area. In addition, the overturned graywacke units in the Rice Bay Dome area have been metamorphosed to sillimanite-bearing amphibolite-facies, whereas the rocks in this map area (unit Agc) have undergone only biotite-bearing greenschist-facies metamorphism. Based on the assumption that the earliest folding in both Ontario and Minnesota was coeval, Day and Sims (1984) proposed that the rocks in Minnesota are on the upper (upward-facing) limb and the rocks in Ontario lie on the lower (downward-facing) limb of a major southwest-plunging recumbent fold. In this model the region was differentially exhumed during erosion, exposing the higher-grade metamorphic rocks in Ontario that reflect the higher temperature and pressure conditions experienced by the lower, more deeply buried limb of the recumbent fold(s).

Direct correlation between D_1 structures in the two areas is equivocal because of the unknown amount of displacement along the intervening high-angle faults. If displacement along the faults was minimal, then the model proposed by Day and Sims (1984) is possible. However, Ojakangas (1972) suggested that movement along the faults was significant.

Nevertheless, the early F_1 folds developed prior to or during the earliest phases of the regional wrench zone tectonism. As deformation proceeded, the apparent flattening of the early D_1 structures intensified. D_1 elements in the region south of the Jackfish Bay fault rotated parallel to the boundary shear zones (represented by the Jackfish Bay and Rainy Lake-Seine River faults). The younger S_2 cleavage and minor F_2 folds were progressively superimposed on the early D_1 tectonic fabric. On the outcrop scale, successively younger foliations fan in orientation from the original S_1 schistosity into the later S_2 cleavage. Clasts and early boudins were deformed into sigmoidal shapes, with strong flattening in S_1 and tails reoriented into the S_2 cleavage direction.

Motion along the high-angle faults probably started during mid- to late-D_2 deformation. Initially, deformation within the fault zones was ductile, producing the phyllonite and protomylonite. During the waning stages of D_3, deformation within the fault zones became more brittle, as recorded by the development of psuedotachylite within the Rainy Lake-Seine River fault zone. Motion along the high-angle faults was terminated by the time of emplacement of the northwest-trending 2,120 Ma diabase dike swarm.

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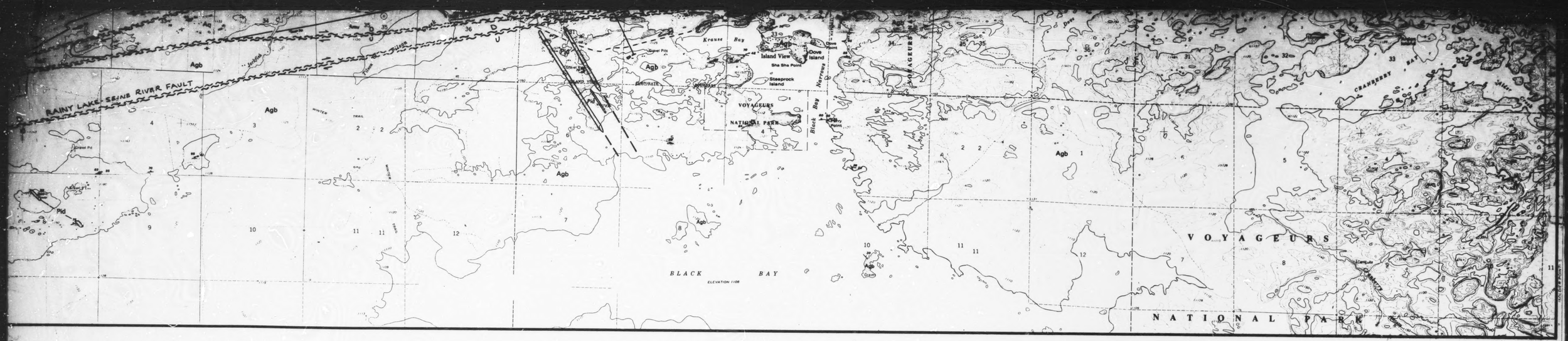
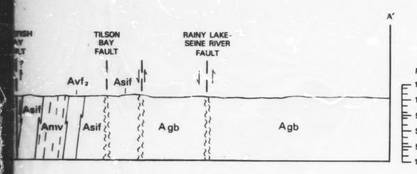
BEDROCK GEOLOGIC MAP OF THE RAINY LAKE AREA, NORTHERN MINNESOTA

By

Warren C. Day

1985





Section A A'

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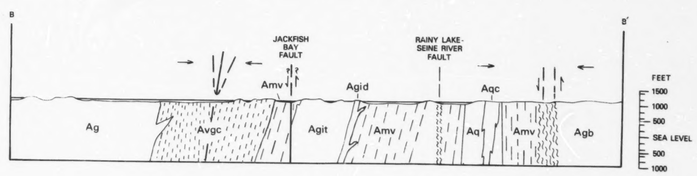
1 0 1 MILE

1 5 0 1 KILOMETER



Section B B'

Mapped July-September, 1983, and with Bruce Brussamle, August, 1984. Additions from reconnaissance mapping by Ojakangas (1972) and Southwick and Ojakangas (1979).

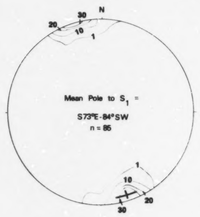


Figure 1

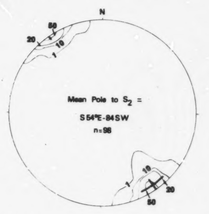
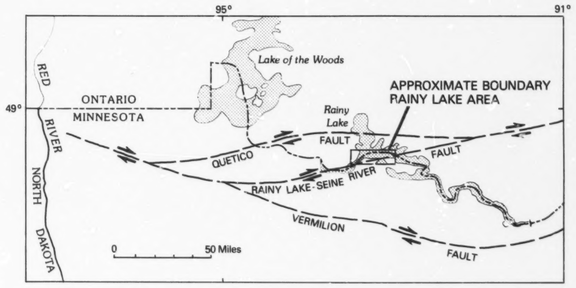


Figure 2



Index map showing the location of the Rainy Lake area and the dextral wrench fault zone bounded by the Rainy Lake-Seine River fault on the south and the Quetico fault on the north.

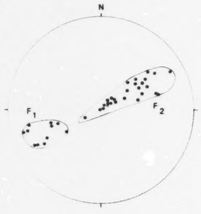


Figure 3

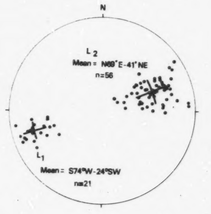


Figure 4

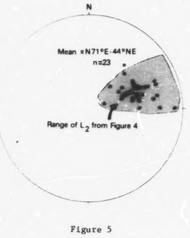


Figure 5

Figure 1.—Density contours of poles to S_1 schistosity. Numbers along contours represent the percentage of data within the area. Solid bars are the range of the standard deviation about the mean.

Figure 2.—Density contours of poles to S_2 cleavage. Numbers along contours represent the percentage of data within the area. Solid bars are the range of the standard deviation about the mean.

Figure 3.—Trend and plunge of F_1 and F_2 fold axes.

Figure 4.—Trend and plunge of L_1 and L_2 mineral lineations. Solid bars represent the range of the standard deviation about the respective mean.

Figure 5.—The trend and plunge of mineral lineations in the Quetico metasediments (unit Agb) south of the Rainy Lake-Seine River fault (solid dots) are similar to L_2 lineations in the Rainy Lake Area to the north. Shaded area delineates the range of the L_2 lineations in the area north of the Rainy Lake-Seine River fault as shown in Figure 4.

MAP SYMBOLS

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Tectonic Interpretation

Oblique convergence along a tectonic axis of maximum compression oriented northwest-southeast caused the regional dextral shear couple that was active along the bounding fault zones represented by the Rainy Lake-Seine River and the Quetico faults. The rocks within the map area have undergone incremental ductile deformation in response to the regional transcurrent tectonic regime.

The earliest phase of deformation (D_1) produced the upward-facing en echelon F_1 folds, and presumably caused early folding in the rocks along structural trend in Ontario. Poulsen and others (1980) reported that the stratigraphic succession was overturned possibly as a result from early recumbent folding in the Rice Bay Dome area in Ontario, which is approximately 20 km to the northeast along strike with the map area. In addition, the overturned greywacke units in the Rice Bay Dome area have been metamorphosed to stillmanite-bearing amphibolite-facies, whereas the rocks in this map area (unit Agc) have undergone only biotite-bearing greenschist-facies metamorphism. Based on the assumption that the earliest folding in both Ontario and Minnesota was coeval, Day and Sims (1984) proposed that the rocks in Minnesota are on the upper (upward-facing) limb and the rocks in Ontario lie on the lower (downward-facing) limb of a major southwest-plunging recumbent fold. In this model the region was differentially exhumed during erosion, exposing the higher-grade metamorphic rocks in Ontario that reflect the higher temperature and pressure conditions experienced by the lower, more deeply buried limb of the recumbent fold(s).

Direct correlation between D_1 structures in the two areas is equivocal because of the unknown amount of displacement along the intervening high-angle faults. If displacement along the faults was minimal, then the model proposed by Day and Sims (1984) is possible. However, Ojakangas (1972) suggested that movement along the faults was significant.

Nevertheless, the early F_1 folds developed prior to or during the earliest phases of the regional wrench zone tectonism. As deformation proceeded, the apparent flattening of the early D_1 structures intensified. D_1 elements in the region south of the Jackfish Bay fault rotated parallel to the boundary shear zones (represented by the Jackfish Bay and Rainy Lake-Seine River faults). The younger S_2 cleavage and minor F_2 folds were progressively superimposed on the early D_1 tectonic fabric. On the outcrop scale, successively younger foliations fan in orientation from the original S_1 schistosity into the later S_2 cleavage. Clasts and early boudins were deformed into sigmoidal shapes, with strong flattening in S_1 and tails reorientated into the S_2 cleavage direction.

Motion along the high-angle faults probably started during mid- to late-D_2 deformation. Initially, deformation within the fault zones was ductile, producing the phyllonite and protomylonite. During the waning stages of D_3, deformation within the fault zones became more brittle, as recorded by the development of pseudotachylite within the Rainy Lake-Seine River fault zone. Motion along the high-angle faults was terminated by the time of emplacement of the northwest-trending 2,120 Ma diabase dike swarm.

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BEDROCK GEOLOGIC MAP OF THE RAINY LAKE AREA, NORTHERN MINNESOTA

By

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1985

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.